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METHODS FOR MEASUREMENT OF SUSPENDED SEDIMENT IN OPEN CHANNELS

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METHODS FOR MEASUREMENT OF SUSPENDED SEDIMENT IN OPEN CHANNELS

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Indian Standard

METHODS FOR MEASUREMENT OF SUSPENDED SEDIMENT IN OPEN CHANNELS

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 23 July 1968, after the draft finalized by the Fluid Flow Measurement Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 Sediment has been defined generally as solid particles which are moved or might have been moved by flow in a channel. It creates numerous problems for the engineer, the agriculturist and the forester all along the channel. It raises the stream bed which increases the flood heights and inundation; it piles up large quantities of sediment behind dams, thereby reducing their capacities and function; it causes the rivers to meander and often to leave their original courses and flow along a new course, devastating vast areas of land; it silts up irrigation and navigation channels making them less efficient. The forester is confronted with the soil erosion and has to devise measures for effective soil conservation.

0.3 When considering a river system as a whole, it can be said that the sediment problem starts at the very source of sediment supply in the upper most drainage area and ends at the river outlet into the sea. However, in certain instances (for example, when the sea is shallow and the current is not able to carry away the sediment discharged by the river) the problem does not end even after the sediment load reaches the sea.

0.4 Therefore for a thorough understanding of the individual problems, a comprehensive knowledge of sediment movements and the methods of estimation of sediment load is absolutely essential.

0.5 In the formulation of this standard due weightage has been given to international co-ordination among the standards and practices prevailing in different countries in addition to relating it to the practices in the field in this country.

0.6 This standard is one of a series of Indian Standards on measurement of liquid and sediment flow in open channels. Other standards published so for in the series are:

*IS: 1191-1959 Glossary of terms used in measurement of flow of water in open channels

*Since revised.

IS : 1192-1959 Velocity-area methods for measurement of flow of water in open channels

IS : 1193-1959 Methods for measurement of flow of water in open channels using notches, weirs and flumes

IS : 1194-1960 Forms for recording measurement of flow of water in open channels

IS : 2912-1964 Recommendation for liquid flow measurement in open channels by slope-area method (approximate method)

IS : 2913-1964 Recommendation for determination of flow in tidal channels

IS : 2914-1964 Recommendations for estimation of discharges by establishing stage-discharge relation in open channels

IS : 2915-1964 Instructions for collection of data for the determination of error in measurement of flow by velocity area methods

0.7 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard covers the methods and techniques of measurement and the instruments used in the estimation of suspended sediment load in open channels, where the flow is uni-directional. This excludes the direct methods of measurement (for which special instruments are necessary) and they will be covered in a separate standard.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions and those specified in IS : 1191-1959† shall apply.

2.1 Sediment Load — It is the total of the sediments that move either in suspension or in contact with the bed. It is the sum of suspended load and bed load. Alternatively, it is the total of ' bed material load ' and the wash load.

*Rules for rounding off numerical values (*revised*).

†Glossary of terms used in measurement of flow of water in open channels (Since revised).

2.2 Bed Load — The sediment in almost continuous contact with the bed while carried by rolling, sliding or hopping along the bed of the stream. Bed load is also divided into contact load and saltation load.

2.2.1 *Contact Load* — The sediment that is rolling or sliding along the bed of the stream in substantially continuous contact with the bed.

2.2.2 *Saltation Load* — The sediment bouncing and hopping along the bed of the stream or moved directly or indirectly by the impact of the bouncing particles.

2.3 Bed Material — Bed material denotes the material, the particle sizes of which are found in appreciable quantities in the shifting portions of the bed.

2.4 Bed Material Load — The coarser part of the sediment load which consists of particle sizes represented in the bed (that is bed material) and which is limited in its rate of movement by the transporting capacity of the channel.

2.5 Suspended Load — That part of the sediment load of a stream which remains in suspension in the flowing water for considerable periods of time without contact with the stream bed, being kept up by the upward component of the turbulence or by colloidal suspension and which moves practically with the same velocity as that of flowing water.

2.6 Wash Load — That part of the suspended load which is composed of particle sizes smaller than those found in appreciable quantities in the shifting portions of the stream bed. It is in near permanent suspension and is transported entirely through the stream without deposition. The discharge of the wash load through a reach depends only on the rate with which these particles become available in the catchment and not on the transport capacity of flow.

2.7 Sediment Concentration — The ratio of dry weight of sediment in a water-sediment mixture to the total weight of a suspension. It is generally expressed in grams per litre or parts per million (by weight).

2.8 Mean Static Concentration of Suspended Load — The concentration which when multiplied by the volume of a reach gives the total weight of suspended load in the reach.

2.9 Mean Concentration of Suspended Load in Motion — The concentration which when multiplied by the discharge of water through a cross-section gives the discharge of the suspended load through the cross-section.

2.10 Sediment Discharge — The weight of sediment transported through a channel per unit time. It is generally expressed as tonnes per day.

2.11 Sediment Hydrograph — The graphical representation showing variation of sediment concentration or discharge with time.

2.12 Terminal Velocity — The limiting velocity reached asymptotically by a particle falling under the action of gravity in a still liquid of infinite extent, at a specified temperature.

3. SEDIMENT AND SEDIMENT MOTION CHARACTERISTICS

3.1 Sources of Sediment — Erosion is caused by water, wind, ice and human activities like cultivation, etc. Clods and aggregates of soil in the catchment area are broken down into small particles which are thrown into suspension and carried away as sediment. Not all the eroded materials get into the stream channel. The total amount of eroded material which travels from source to a downstream measuring point is termed as the 'sediment yield'.

3.2 Rate of Sediment Production — The sediment yield of a catchment is dependent on a complex of hydro-physical conditions. The significant physical features are the size and slopes of the catchment area, land use, pattern of channelization and erodibility of the soil. The significant hydrologic parameters are rainfall and run off, particularly the peak values of run off.

Sediment yield data is reduced for purposes of comparison to the yield per unit of the catchment area and referred to as the 'Sediment Production Rate' expressed in tonnes or cubic metre of sediment per square kilometre of the catchment area per year.

3.3 Sediment Motion and Sediment Load — For a proper comprehension of sediment movement and related terms, the flow of water over an artificially flattened bed of sediment may be considered. From no movement of sediment at very low velocities, some particles begin to move with the increase of velocity by sliding along the bed (contact load) and then by making short jumps (saltation load); at still higher velocities particles are thrown into suspension and prevented from coming into contact with the bed by the upward component of the turbulence or by colloidal suspension (suspended load).

'Contact load', 'saltation load' and 'suspended load' may occur simultaneously and the border lines between these are not well defined. This difficulty is avoided in practice by dividing the '*total load*' into 'suspended load' and 'bed load'. The 'bed load' moves at a lower velocity than the layer of water through which it is travelling, the traction on it being exercised through the fluid drag. The total load may also be divided into 'bed material load' and 'wash load' the former constituting the coarser part of the sediment load moved by the transporting capacity

of the channel which may settle and the latter the fine suspended material which does not settle in the existing conditions of flow.

3.4 Bed Configuration — The corresponding bed configuration with increasing velocity are *ripples* (at the early stage of sediment motion) which move downstream at velocities smaller than the flow velocity; then with increasing Froude number and boundary shear stress, the ripples change into *dunes*, which disappear at some higher velocity and the bed becomes *flat*; at still higher velocities, sand waves (anti-dunes) form which usually move upstream and are accompanied by waves on the water surface.

3.5 Properties of Sediment — The transportation of sediment depends as much upon the properties of the sediment as upon the hydraulic characteristics of flow. The properties of sediment are defined by individual particle characteristics and bulk characteristics.

3.5.1 *Properties of Individual Particles* — The sediment size is the most commonly used parameter to designate the properties of individual particles. While the size of sediment and its packing directly affect the roughness of the bed, the terminal velocity of the particle directly characterises its reaction to flow and governs the movement of sediment. This in turn depends upon the specific weight, shape and the size of the particle.

3.5.1.1 Since natural sediment particles are of irregular shape a single length or diameter to characterize the size shall be chosen. Four such diameters as defined below are used for different particles' size or purposes [for example, (a) for coarse and medium size particles, and (d) for the fine particles which cannot be separated by sieves]. The nominal diameter has little significance in sediment transport, but is useful in the study of sedimentary deposit.

a) *Sieve diameter* — The length of the side of the smallest square opening through which the particle will just pass.

b) *Projected diameter* — The diameter of a circle which just encloses the projected image of the particle when viewed in the plane of maximum stability.

c) *Nominal diameter* — The diameter of a sphere of the same volume as the given particle.

d) *Sedimentation diameter* — The diameter of a sphere of the same specific weight and the same terminal settling velocity as the given particle in the same sedimentation fluid.

3.5.2 *Bulk Characteristics* — As sediments consist of large number of particles differing in size, shape, specific gravity, terminal velocity, etc, it is essential to find some parameters that can represent the characteristics of the group of particles as a whole. Therefore, a sample of sediment is usually divided into certain class intervals according to the characteristics (like size, terminal velocity, etc) and the percentage of the total in each

class by weight for the particular characteristic is determined and the frequency distribution curves are drawn and their parameters (mean, standard deviation, etc) are determined.

4. MEASUREMENT OF SUSPENDED SEDIMENT LOAD

4.1 Principles of Measurement

4.1.1 The concentration of suspended sediment (c_i) and the current velocity (v_i) are measured practically simultaneously at a large number (m) of points in the sampling area of a cross-section. Each concentration and velocity is representative of a small area (a_i) of a sampling cross-section. The sum of all the areas (a_i) is the sampling area (A).

The average static concentration $\bar{c}_s$ is given by:

$$\bar{c}_s = \frac{\sum_{o}^{m} c_i}{m}$$

The mean concentration of suspended sediment load in motion $\bar{c}_m$ is given by:

$$c_m = \frac{\Sigma c_i\ v_i\ a_i}{\Sigma a_i\ v_i} \text{ or } = \frac{\Sigma c_i\ v_i\ a_i}{Q}$$

where

$Q = \Sigma a_i\ v_i$, is the discharge in the sampling area.

The suspended sediment load through the sampling area is the product of the mean concentration in motion and the discharge, that is, $\bar{c}_m \times Q$

Thus, for one year the total weight of solids transported is

$$\sum_{1}^{365} \bar{c}_{mi}\ Q_i$$

NOTE — As a suspended sediment sampler cannot take samples near the bed of the channel where the concentration is quite high, the suspended sediment load is determined for, and applicable only to, the 'sampled zone' of the channel.

4.2 Units of Measurement — The concentration of suspended sediment is expressed in g/l (Kg/m^3) or parts per million (by weight).

4.3 Selection of Site — Since sediment load is obtained as a product of mean concentration of the sediment load in motion and the corresponding discharge in the river, the site for silt observation should normally be the same as that for discharge observations and should satisfy the conditions laid down in IS : 1192-1959*.

*Velocity-area methods for measurement of flow of water in open channels.

4.4 Measurement of Discharge — For the purpose of this standard the discharge measurements shall be made in accordance with IS : 1192-1959*.

4.5 Requirements for Sampling of Suspended Load

4.5.1 The concentration of suspended load not only changes from point to point in a cross-section but also fluctuates from moment to moment at a fixed point. The kind of sampler and the technique of sampling used will depend on a large number of factors. The discharge of sediment load per unit width at a vertical in a cross-section can be determined either by integrating over the depth the products of the concentration of the suspended load and the velocity measured simultaneously at each of a number of points in the vertical or by using an integrating depth sampler which automatically takes a sample in which the concentration of suspended load is the mean concentration in motion (*see* **4.6**).

The suspended sediment concentration as well as the grade of sediment in a flowing stream increases from top to bottom and it also varies transversely across the section. The variation depends upon the size and shape of the cross-section, the stage of flow and other channel characteristics. Hence a preliminary investigation has to be made to select the sampling points on a vertical and also the number and location of the sampling verticals, taking into consideration the accuracy desired and the resources available.

A comparative summary of the sampling methods and their reliability is given in Table 1 and the methods are described in **4.6.**

Both for measurements and the determination of the point of mean concentration of sediment, sediment concentration should be determined at several points in a vertical like 0·1, 0·2, 0·3, 0·4, 0·5, 0·6, 0·7, 0·8 and 0·9 depth (or the lowest practicable point).

4.5.2 The procedures for obtaining the mean sediment discharge per unit area and the mean sediment concentration in motion at the vertical are:

a) Draw the velocity distribution and sediment concentration curves as in Fig. 1A and 1B. The curves shall be drawn up to the sampled zone.

b) Find the products of c (concentration) $\times$ v (velocity) at corresponding points and draw the rate of sediment discharge curve as in Fig. 1C.

c) Assuming unit width, find the areas of Fig. 1A (qw) and Fig. 10 (q_s). This may be done graphically by planimetering or numerically by a rule such as the trapezoidal rule. These areas directly give the water and sediment discharges.

*Velocity-area methods for measurement of flow of water in open channels.

d) The mean sediment concentration in motion at the vertical and the mean sediment discharge per unit area at the vertical are $\bar{c}_m = \frac{q_s}{q_w}$ and $\bar{q}_s = \frac{q_s}{D}$ respectively, where D is the depth (up to sampled zone).

NOTE 1 — This method is more laborious than would ordinarily be justified for routine sediment measurement. However, for preliminary investigation for determining the point of mean concentration such experiments should be repeated for various stages of flow.

NOTE 2 — The fine sediment (below 0·075 mm diameter) is generally found to be uniformly distributed throughout the vertical and a single sample at any depth is likely to be sufficient for determining its concentration.

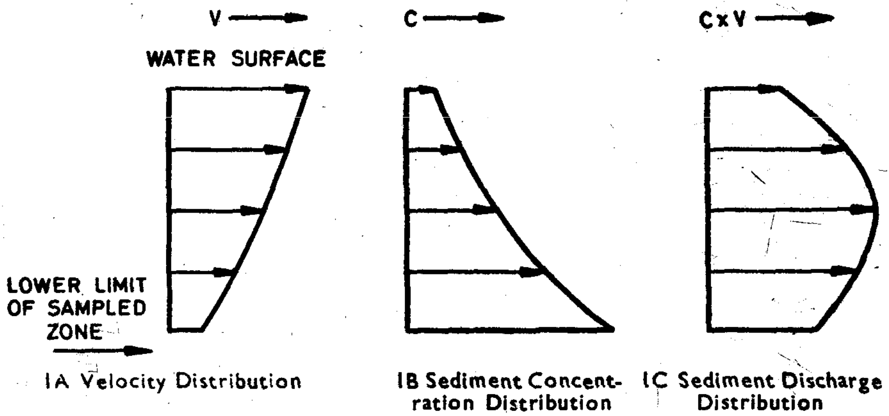

FIG. 1 SEDIMENT DISCHARGE COMPUTATION

4.5.3 *Selection of Verticals* — For the determination of the minimum number of verticals representing the sediment distribution across the stream, one of the following two procedures should be followed:

a) The section should be divided into as large a number of equally spaced segments as practicable to be completed in one observation. The mean concentration in motion in each vertical in the centre of the segment [**4.5.2** (d)] should be obtained and weighted with respect to the stream discharge in the respective segment. This will give an indication of the distribution of sediment in the entire section for the particular stage of flow.

b) The stream section is divided into a large number of segments of approximately equal discharge and sediment samples are taken at the centroid vertical of each equal discharge segments. This

TABLE 1 METHOD OF SELECTING SAMPLING POINTS IN A VERTICAL

(*Clause* 4.5.1)

SL No.	METHOD AND DESCRIPTION	DISCUSSION	RELIABILITY AND ACCURACY FOR DETERMINING		PRACTICAL CONSIDERATION	NUMBER OF SAMPLES AND ANALYSES PER VERTICAL
			Concentration Only*	Concentration and Particle Size		
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	*Single-point* A single sample secured at the surface	Arbitrary method unless coefficients have been determined from previous, more complete sampling, and then it is somewhat empirical	Not reliable or necessarily accurate even when a coefficient has been determined	Not at all reliable or accurate	Simplest of all present methods, rapid and easy to use. Readily adapted for use by unskilled observers. Requires previous, more exact sampling for justification	One sample and one laboratory analysis
ii)	*Single-point* A single sample secured at any point in the vertical other than the surface	Arbitrary method unless coefficients have been determined from previous, more complete sampling, and then it is somewhat empirical. A common arbitrary point has been 0·6 depth	Generally not reliable or accurate even when a coefficient has been determined, but more so than a single surface sample. Thoroughness of preliminary investigations will determine, somewhat, the reliability and accuracy	Not reliable or accurate	Simple, rapid, and easy to use, but fractional depth measurements make it less adaptable to use by unskilled observers than single surface method. Requires previous, more exact sampling for justification	One sample and one laboratory analysis
iii)	*Two-point* Two points selected arbitrarily for convenience and adaptability to the skill of the observer	Arbitrary method with no rational justification	Generally not reliable or accurate for all conditions of a given stream	Generally not reliable or accurate	Fairly simple, rapid, and easy to use. May be used by dependable observers even though inexperienced	Two samples may be combined if of equal volume for a single analysis
iv)	*Three-point* Arbitrary selection of points at surface, mid depth and bottom with equal weights	Points located arbitrarily	Not necessarily reliable or accurate for all stream conditions	Not necessarily reliable or accurate	Sampling at surface, mid-depth, and bottom is the most simple and easiest to use of all methods requiring more than two samples may be used by dependable observers even though inexperienced	Three samples may be combined if of equal volume for a single analysis
v)	*Three-point* Arbitrary selection of points at surface, mid-depth, and bottom with weights of 1, 2, and 1 applied, respectively	Basis of method is the assumption that the averages of surface and mid-depth sample represent upper-half of discharge and average of mid-depth and bottom represents lower-half	Not necessarily reliable or accurate for all stream condition	Not necessarily reliable or accurate, but more so than three points, surface mid-depth, and bottom with equal weights	Sampling at surface, mid-depth, and bottom is the simplest and the easiest to use of all methods requiring more than two samples. May be used by dependable observers even though inexperienced	Three samples. If of equal volume, surface and bottom samples may be combined for single analysis
vi)	*Precise* A relatively large number of point samples at known locations in each vertical, simultaneous with velocity measurements	Rational method for use primarily in special investigations. Number of sampling points depends upon depth of stream, the velocity and sediment distribution, and the degree of accuracy desired	Reliable and accurate. Accuracy depends upon the curvature of the velocity and sediment distribution curves and number of samples. The most accurate method in use at present	Reliable and accurate. Accuracy depends upon curvature of particle distribution curves, and number of samples. The most accurate method in use at present	Not adapted to routine sampling because of the excessive work required. Its use is limited to research or preliminary investigations. Laboratory work excessive as all samples must be analysed separately	Minimum of four or five samples all to be analysed separately

*For methods where coefficients are used, comments apply only to individual observations or short period investigations, as over long periods, totals may have a fair degree of accuracy.

(*Continued*)

TABLE 1 METHOD OF SELECTING SAMPLING POINTS IN A VERTICAL — *Contd*

Sl No.	Method and Description	Discussion	Reliability and Accuracy for Determining		Practical Consideration	Number of Samples and Analyses per Vertical
			Concentration Only*	Concentration and Particle Size		
(1)	(2)	(3)	(4)	(5)	(6)	(7)
vii)	*Straub* Sampling at 0·2 and 0·8 depth, applying coefficient obtained by mathematical derivation for both linear and curvilinear sediment distribution for linear distribution values weighted 5/8 and 3/8 for 0·2 and 0·8 depth, respectively	Rational method, best adapted for use where the vertical sediment distribution curve approximates a straight line and the velocity distribution is fairly constant	Accuracy and reliability depends almost entirely upon the agreement of the actual to the assumed sediment and velocity. In most cases quite reliable	Theoretically not sound if sediment distribution is curvilinear, but, practically, one of the most reliable methods	Field work relatively simple for skilled observer but adaptable also to dependable observers, even though inexperienced	Two samples and two analyses
viii)	*Luby* Sampling points selected at the middle of increments of depth representing equal portions of stream discharge	Rational method if a sufficient number of samples are collected. The samples if of equal volume, may be combined and the composite is representative of the mean concentration and composition in the vertical. Number of points with respect to depth depends primarily upon curvature of sediment distribution curve; to a lesser extent, generally, upon curvature of vertical velocity curve	Reliable and accurate if a sufficient number of samples are collected. One of the most reliable and accurate of the present methods except the precise	Fairly reliable and accurate if a sufficient number of samples are collected. One of the most reliable and accurate of the present methods except the precise. Enough samples should be taken so that one will be close to the stream bed	Requires either an assumed velocity distribution or previous velocity measurements. Too complicated for use except by trained hydrographers. Because of sampling more points a better representation of the actual sediment distribution will probably be obtained than with the Straub method	Minimum of five samples. May be combined if of equal volume for a single analysis
ix)	*Depth-integration* Single sample collected from all points in the vertical usually obtained by lowering and raising a slow filling sampler at constant rate. These usually consist of ordinary milk bottle types or specially designed slow-filling samplers	Rational method only if sample is collected proportional to velocity	Relatively reliable under usual conditions but its accuracy varies as most of the present equipment does not sample proportional to the velocity and many samplers do not approach close enough to the bottom. As used, accuracy depends upon depth of stream and type of sampler	Relatively reliable under usual conditions but its accuracy varies as most of the present equipment does not sample proportional to the velocity, and many samplers do not approach close enough to the bottom. As used, accuracy depends upon depth of stream and type of sampler	As commonly used with simple slow-filling samplers this method is simple, rapid, easy to use, and well adapted to dependable ovservers, even though inexperienced. No previous measurements necessary	One sample and one analysis

*For methods where coefficients are used, comments apply only to individual observations or short period investigations, as over long periods, totals may have a fair degree of accuarcy.

gives the required sediment distribution across the stream for the particular stage of flow.

There is no firm relationship between the stage and the location of the point of mean concentration in motion. Therefore, the above observations shall be made for different stages of flow. It is desirable to have larger frequency of observations on a limited number of verticals at the high flood stages; and the endeavour should be to ensure measurements at least once a weak during high flood stages and once during the highest floods or during the occurrence of a flashy spate. The more frequent the observations the better the overall estimate is likely to be and, wherever possible, sediment observations should be made as frequently as discharge observations are made on perennial streams.

NOTE 1 — When the investigation is not important enough to merit preliminary experiments, Table 2 may be used as a guide for locating the number of verticals and their approximate location across the section. It is not always correct unless a considerable amount of preliminary work has been done at a given sampling cross-section which justifies it to assume a relationship between distribution of concentration in motion and velocity.

NOTE 2 — For routine observations, a few verticals either equally spaced or representing segments of equal discharge which will give almost the same mean sediment concentration in motion, as the greater number of verticals in the preliminary experiments shall be selected. The number of verticals chosen shall preferably be not less than 3.

NOTE 3 — The method (b) can be used in practice only in canals or non eroding channels.

TABLE 2 SELECTION OF VERTICALS

(*Clause* 4.5.3, *Note* 1)

SL No.	WIDTH OF THE RIVER	NUMBER OF VERTICALS	LOCATION OF VERTICALS IN NORMAL SECTION WITH SLOPING SIDES	LOCATION OF VERTICALS IN STREAMS OF UNIFORM DEPTH AND VELOCITY
(1)	(2)	(3)	(4)	(5)
i)	Less than 30 m	3	25, 50 and 75 percent of the width	17, 50 and 83 percent of the width
ii)	30 — 300 m	5	20, 35, 50, 65 and 80 percent of the width	10, 30, 50, 70 and 90 percent of the width
iii)	Over 300 m	7	15, 30, 40, 50, 60, 70 and 85 percent of the width	7, 21, 36, 50, 64, 79 and 93 percent of the width

NOTE — These are suggested for tentative adoption in natural and artificial channels until by experimentation more suitable location and spacing of verticals are determined.

4.6 Methods for Routine Sampling

4.6.1 The best known method is that for the determination of the point of mean concentration in motion (**4.5.2**). A number of other commonly used methods (such as Straub, Luby, Depth integration) have been developed for determining the average sediment concentration in motion in a vertical. In general, these methods are based upon analysis of factors which influence the movement of sediment loads in streams and are therefore to be preferred to the one-point and two-point methods.

4.6.2 *One-Point Method* — In this method the sampler shall be immersed to the point of mean sediment concentration in motion as determined from the preliminary experiments in **4.5.2.** The depth from the surface $h_{\bar{c}_m}$ at which to take the water sediment sample corresponding to the mean concentration in motion $\bar{c}_m$ may be obtained from Fig. 1. The sediment concentration of the sample taken at this depth, $h_{\bar{c}_m}$ is multiplied by q_w (that is, water discharge per unit width in the vertical) to get the suspended sediment discharge per unit width in the vertical q_s. The mean suspended sediment discharge per unit area is obtained by dividing q_s by D, the depth of the sampled zone.

4.6.2.1 If the sample is taken at one point only of a single vertical at the centre of the stream the position in the vertical at which the sample is taken should be that at which the concentration of suspended load is the mean concentration of suspended load in motion for the whole cross-section. If this is not known, then the sample is taken at the position on the central vertic l where the concentration is the mean concentration of suspended load in motion in that vertical. This concentration is multiplied by the discharge of the stream to give the total suspended sediment load.

4.6.2.2 More correctly the value of the concentration should be multiplied by the discharge of the sampled area of the stream but since this is usually not known, the concentration is multiplied by the total discharge, as an approximation.

4.6.2.3 Since the sediment concentration distribution curve is different for different size ranges, a sample taken at the mean sediment concentration point (for the sample as a whole) will not generally give the true size distribution. Only a composite representative sample taken either by a depth integrating sampler or made up of point samples taken at more than one point on the vertical and weighted in proportion to velocity can give the overall average concentration and size distribution of the sediment load in motion. If the point sampling method is used it is better to make a size analysis on each sample and to plot the product of the velocity and the concentration of particles in a given size range against the depth.

4.6.2.4 In the absence of previous experiments, a common practice has been to sample at 0·5 or 0·6 depths, but this method will give only approximate results for the overall mean concentration. Size distribution may not be obtained by this method.

4.6.2.5 At times, were sampling at the position of mean concentration of sediment in motion is not possible (for example, in hilly or boulder streams flowing at high velocity) the samples are collected from a point near the surface and their values multiplied by an appropriate factor (if any), determined from preliminary experiments for converting the concentration at the surface to approximate mean concentration in motion. This conversion factor can be strictly applied only to the particular stage of flow and the channel and sediment conditions under which it has been obtained. However, size distribution cannot be obtained by this method.

4.6.3 *Multi-point Method*

4.6.3.1 Samples should be taken at 2, 3 or more points in the vertical and if weighted in proportion to the corresponding current velocities, the concentration of the weighted sample can be taken as the mean concentration in motion. However, for simplicity as an approximation (particularly where it is difficult to determine the corresponding velocities), samples are taken at 2 or 3 or more points along the vertical and their average taken as the mean static concentration, and this is multiplied by the average velocity to give the mean concentration in motion. In general, the greater the number of sampling points the greater will be the accuracy of results.

4.6.3.2 In the two-point method, two samples shall be taken, one below the surface undulation and the other near the bottom (for example, 0·9 depth or the lowest practicable depth) of equal volume. A single analysis shall be made of the combined sample.

4.6.3.3 In the three-point method, samples shall be taken below the surface undulation, mid-depth and near the bottom (for example, 0·9 depth or the lowest practicable depth) with the mid-depth sample given twice the weight of the others. A composite sample made up of two samples from mid-depth and one each from surface and bottom, all of equal volume, shall be used for both concentration and size analysis.

NOTE — If preliminary experiments as described in **4.5.2** have been conducted, correction factors based on the same shall be applied.

4.6.4 *Other Methods for Determining Average Sediment Concentration*

4.6.4.1 *Straub method* — In this method, samples are taken at 0·2 depth and 0·8 depth and the values are weighted 5/8 and 3/8 respectively as given below:

$$\bar{C}_m = \tfrac{5}{8}\, C_{0\cdot 8h} + \tfrac{3}{8}\, C_{0\cdot 2h}$$

The method is satisfactory for determining the sediment concentration in motion over a considerable range of conditions, but not reliable for sediment size distribution.

4.6.4.2 *Luby method* — In the Luby method the samples are obtained from areas of equal discharge. To obtain samples representing equal

portion of the water discharge the area under the vertical velocity curve is divided into equal parts and the sampling points are to be located at the centroids of these areas. Equal volumes of the samples should be combined and the composite sample used to determine both the mean sediment concentration in motion and the particle size distribution in the vertical.

4.6.4.3 *Depth integration method* — This method of sampling is based on the premise that the sampler designed specifically for the purpose fills at a rate proportional to the velocity of the approaching flow and that by traversing the depth of the stream at a uniform speed the sampler will receive at every point in the vertical a sample of the water sediment mixture, at a rate which will be proportional to instantaneous velocity. Only a slow-filling type of sampler shall be used for depth integration. The sampler shall be lowered to the bottom of the stream at a uniform rate and shall be raised again without pausing at the bottom to the surface at a uniform but not necessarily at the same rate, sampling continuously during both periods of transit, or it may be designad to sample at a uniform rate one way only. However, if the sampler is opened at the bottom of the vertical and is integrated on the ascending trip only, a specially designed sampler should be used where the air pressure in the container at the time of opening is balanced by the hydrostatic pressure surrounding the sampler. The depth integration method of sampling requires only one sample from each vertical and gives fairly reliable average of the size distribution of the particles of the stream. This method offers easier field procedure for computation of suspended sediment loads. Use of the depth integrating sampler is only possible if the sampler can be lowered to the bottom and raised again to the surface before the sample container fills with water. The depth of water in which it may be used varies inversely as the product of the velocity and the size of the sampling nozzle. Under favourable circumstances it may be used to sample in depths up to 6 m.

4.7 Computation of Suspended Sediment Load

4.7.1 For computation of sediment load passing down a cross-section it is assumed that the average sediment discharge per unit area between two verticals is equal to the mean of the sediment discharge rates observed at each vertical. The product of this mean and the area between the verticals gives the sediment discharge for the area. The total sediment load passing the cross-section is obtained by totalling the sediment and the discharges passing through each of these segmental areas into which the cross-section has been divided by the verticals.

NOTE — Allowance where necessary should be made for the sediment load carried between the two end-verticals and the banks by closer spaced verticals.

4.7.2 In the equal-discharge-increments (EDI) method, a measurement of water discharge is made from which the spacing of verticals so as

to divide the water discharge into equal segments is determined. Then the sampler is lowered and raised from top to bottom and back at the centroid vertical of each equal discharge zone. The quantity in each centroid sample should be proportional to the water discharge in the segmental section, however, if the location of verticals has been precisely determined equal volumes of sediment sample should be taken. The composite sample represents the mean concentration in motion at the stream section.

4.7.3 If equally spaced verticals are used, the mean concentration of sediment load in motion is determined for each vertical. These concentrations are multiplied by the partial discharge in the two half segments on either side of the vertical and the products are added to give the total sediment discharge. The computation of sediment load with equally spaced verticals is facilitated if a depth integrating sampler is used. Since the sampler is designed to admit water sediment mixture at a rate nearly proportional to the local velocity of the stream at the sampler intake, the samples from each vertical in this equal transit rate (ETR method) is automatically weighted by discharge. The composite of all the samples is a nearly correct sample of the whole stream concentration. This concentration multiplied by the discharge yields the total suspended sediment discharge.

NOTE — If, during use, the integrating point sampler is lowered and raised at a constant velocity in each of the verticals and if at no vertical does the sample bottle become completely full, then the whole of each of the samples may be mixed and the concentration of the mixture will be the mean concentration of sediment in motion at the cross-section. If the velocity with which the sampler traverses the vertical is not the same at all verticals, then the mixture of the samples except in proportion to the mean velocity in the corresponding vertical will not give a valid average sample.

4.7.4 A form for computation of suspended load is shown in Table 3.

4.8 Samplers

4.8.1 In order that samples taken by a sampler should be truly representative, of the sediment concentration of a stream at the point of sampling the ideal samplers should fulfil the following technical requirements:

a) The sampler should be stream-lined so as to avoid disturbance in the sediment flow;

b) The velocity of inflow at the mouth of the sampler should be equal to the velocity of stream flow;

c) The mouth of the sampler should always face the direction of current;

d) The mouth should be outside the zone of disturbance of flow set up by the body of the sampler and its operating gear;

e) Filling arrangement should be very smooth without causing sudden in rush or gulping;

f) The container should be easily removed, readily capped and transported to a laboratory without loss of contents;

g) The sampler should be able to collect samples at the desired depth (from surface down to 0·3 metre from the bed) without disturbing or contaminating the water sediment mixture at other points while the sampler is being raised or lowered;

h) The sampler should be portable but sufficiently heavy to minimize deflection from the vertical due to current drag;

j) It should be robust and simple in design and construction and require minimum care for maintenance and repair; and

k) The volume of the sample should be sufficient for determination of concentration and size analysis.

None of the samplers at present in use may satisfy all the requirements. Some of the samplers approaching the ideal conditions are unfortunately very costly and cumbersome for use in the field.

4.8.2 Various types of suspended sediment load samplers have been designed with a view to complying with most of the above requirements and a few of these types are:

a) Vertical,

b) Instantaneous vertical,

c) Instantaneous horizontal,

d) Bottle,

e) Bottle (modified),

f) Point integrating,

g) Depth integrating, and

h) Pump.

The characteristics and drawbacks of each of these samplers have been briefly described in Table 4.

TABLE 3 FORM FOR COMPUTATION OF SUSPENDED SEDIMENT DATA

(*Clause* 4.7.4)

For the Month of________________

State________________ Circle________________ Division________________

Sub-Division________________ River________________ Site________________

Reduced Distance________________ Gauge No.________________ Reduced Level of Zero of Gauge________

Date	Mean Gauge Metres	Discharge in m^3/s	Run Off in Hectare Metres	Coarse Sediment (Particles Above 0·2 mm Diameter)			Medium Sediment (Particles Between 0·2 and 0·075 mm Diameter)			Fine Sediment (Particles Below 0·075 mm Diameter)				Total Sediment			Mode of Sampling	Remarks
				g/l	Hectare Metres	Percentage	g/l	Hectare Metres	Percentage	*$R^1 - R = (F+D)K$	g/l	Hectare Metres	Percentage	g/l	Hectare Metres	Percentage		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
1																		
2																		
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7																		
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24																		
25																		
26																		
27																		
28																		
29																		
30																		
31																		
Total																		
Mean																		
Grand Total																		
Mean Mean																		

*R^1 = hydrometer reading of the river water

R = hydrometer reading of the distilld water at the same temperature

D = dissolved material per litre

F = fine sediment in g/l

K = multiplying factor for hydrometer

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TABLE 4 CHARACTERISTICS OF SUSPENDED SEDIMENT LOAD SAMPLERS

(*Clause* 4.8.2)

SL No.	TYPE	DESCRIPTION	DISTURBANCE TO FLOW CHARACTERISTICS	INTERMIXING OF SAMPLE WITH WATER	SAMPLING ACTION	FIELD HANDLING	ADAPTABILITY TO VARIOUS FIELD CONDITIONS
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Vertical pipe	With a vertical cylinder or pipe forming the container. When the sampler is lowered to the desired depth, water sediment mixture flows upward through the container. Valves at either end close and trap the sample	Excessive	Generally excessive	Instantaneous	Necessary to transfer into another container	Offers considerable resistance to current. Not satisfactory when close to stream bed
ii)	Instantaneous vertical	A vertical sampler with arrangement to open the sampler for the instantaneous (rapid) intake of samples at the desired time and depth	Effect not evaluated	None	Instantaneous	Necessary to transfer into another container	Not satisfactorily streamlined or adapted for use near stream bed
iii)	Instantaneous horizontal	With a horizontal cylinder equipped with end valves which can be closed suddenly to trap instantaneous samples at any desired time and depth	Tendencies minimised effects not evaluated	Slight possibility	Instantaneous	Necessary to transfer into another container	Allows sampling very close to stream bed. Adaptable to any stream or depth
iv)	Bottle	Consisting of a standard container held in a case with device for lowering and opening at the sampling point. The mouth is kept open for the minimum time required to fill up the bottle	Excessive effect not evaluated	Excessive, if not opened and closed at site	Bubbling or slow-filling after initial rush	Container with sample removable	Not capable of sampling close to bed of stream. Has got high efficiency in trapping fine grade sediment and the efficiency is less with the increase in grade
v)	Bottle (modified)	Consisting of a litre capacity container fitted in a case with device for lowering or raising and opening at the sampling point. Provided also with separate water intake and air exhaust device for equalising pressure inside and outside the container	Appreciable. Effect not evaluated	Excessive, if not opened and closed at the sampling point	Slow-filling; no initial inrush present	Container with sample detachable	Not capable of sampling close to the stream bed
vi)	Point integrating	Designed to fill continuously at a given point over an interval of time and hence is provided with an opening and closing mechanism and as well with a pressure equaliser to minimise initial inrush of water	Tendencies minimised but not evaluated	Some extent, if not opened and closed at site	Smooth filling, minimum initial inrush	Container with sample removable	May be limited by depth of stream
vii)	Depth integrating	Designed to fill continuously during lowering from surface to bed (as well on the return trip from bed to surface). The samplers designed to fill during lowering only are provided with a foot trigger which closes both inlet and exhaust upon contact with the bed	Excessive	Possibility to some extent	Smooth filling. Although the sampled filament will enter the intake nozzle at an angle, provisions exist for making inlet velocity essentially equal to the local velocity of the stream	Container with sample removable	Capable of sampling close to the bed of the stream
viii)	Pump	The sediment mixture is sucked in through a pipe or hose, the intake of which is placed at the desired sampling point. By regulating the intake velocity, an undisturbed sample can be obtained	Tendencies minimized with proper control of intake tube and velocities	None	Time-integrated	Container with sample removable	Present design not portable. Somewhat limited in use due to resistance to current. Heavy sediment loss in pipe line may limit use

AMENDMENT NO. 1 DECEMBER 1979

TO

IS:4890-1968 METHODS FOR MEASUREMENT OF SUSPENDED SEDIMENT IN OPEN CHANNELS

Addendum

(*Page 13, clause 4.5.3*) - Add the following new clause after 4.5.3:

'4.5.3.1 The selection of verticals on the basis of equally spaced segments [according to the procedure given in 4.5.3(a)] will be easy in field practice, whilst the selection of verticals on the basis of segments of equal discharge [according to the procedure given in 4.5.3(b)] will involve practical difficulty since the verticals in this case will be changing with stages. In order to get the mean sample for the preferred method [4.5.3(a)] the samples should be mixed in proportion to the discharges in case of equally spaced segments.

In practice the number of samples for laboratory analysis with method given in 4.5.3(a) is large and creates difficulties. Therefore, in field practice a suspended sediment sample is collected from each of a large number of equally spaced verticals. These samples are grouped in 5 to 7 segments taking into consideration the quantity of discharge passing through the different segments, so that each segment nearly represents equal discharges. The samples of each of the groups are mixed together and analysed for working out the mean concentration of the segment. The mean concentration of the stream is the mean of the concentrations of the segments.'

(BDC 17)

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